Abstract

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Title: **Architectural Design for a Mars Communications & Navigation Orbital Infrastructure**

Authors: **R. J. Cesarone, R. C. Hastrup, D. J. Bell, R. B. Roncoli**

Jet Propulsion Laboratory, California Institute of Technology

K. Nelson

Stanford Telecommunications, Inc.

The planet Mars has become the focus of an intensive series of missions that span decades of time, a wide array of international agencies and an evolution from robotics to humans. The number of missions to Mars at any one time, and over a period of time, is unprecedented in the annals of space exploration. To meet the operational needs of this exploratory fleet will require the implementation of new architectural concepts for communications and navigation.

To this end, NASA's Jet Propulsion Laboratory has begun to define and develop a Mars communications and navigation orbital infrastructure. This architecture will make extensive use of assets at Mars, as well as use of traditional Earth-based assets, such as the Deep Space Network, DSN. Indeed, the total system can be thought of as an extension of DSN nodes and services to the Mars in-situ region. The concept has been likened to the beginnings of an interplanetary Internet that will bring the exploration of Mars right into our living rooms.

The paper will begin with a high-level overview of the concept for the Mars communications and navigation infrastructure. Next, the mission requirements will be presented. These will include the relatively near-term needs of robotic landers, rovers, ascent vehicles, balloons, airplanes, and possibly orbiting, arriving and departing spacecraft. Requirements envisioned for the human exploration of Mars will also be described. The important Mars orbit design trades on telecommunications and navigation capabilities will be summarized, and the baseline infrastructure will be described. A roadmap of NASA's plan to evolve this infrastructure over time will be shown. Finally, launch considerations and delivery to Mars will be briefly treated.

Four performance goals are very important in the design of the Mars orbital infrastructure:

1. Redundant Equatorial Coverage. Many of the Mars science missions focus on regions within the +/- 20 latitude region. Related to this, the first manned missions are planning near equatorial landing sites. Thus, one of the goals is to provide high capacity coverage of the equatorial regions, even in the event of the loss of any single spacecraft in the constellation. The practical result of this is to deploy two spacecraft in near equatorial orbits.

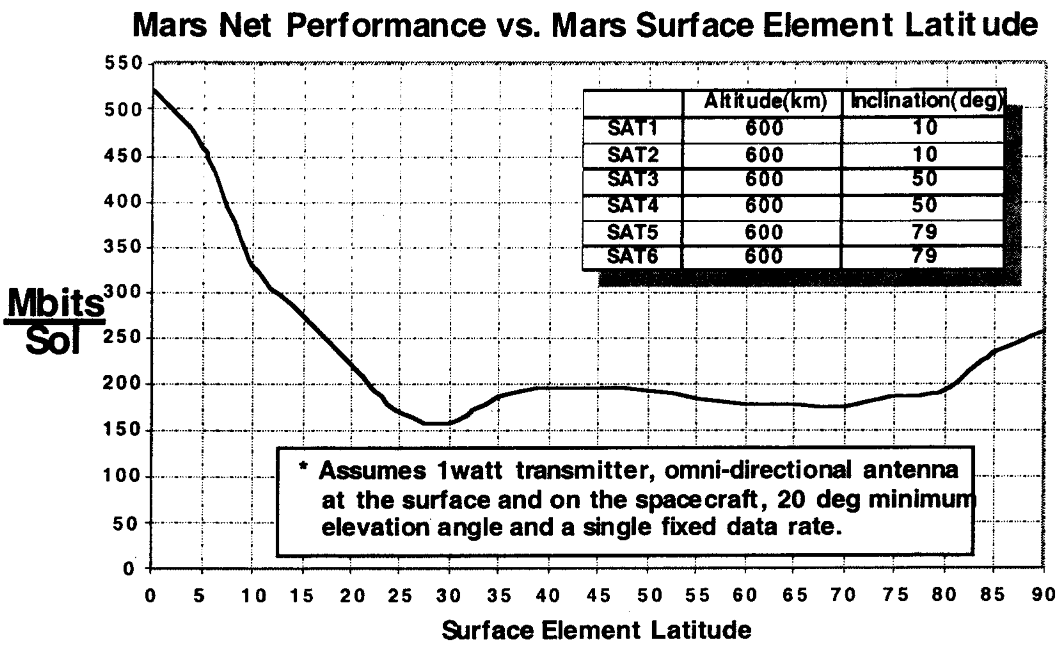
2. Redundant Global Coverage. Some mission types such as global seismic or meteorological networks require global low capacity coverage. Since a single satellite in near-polar orbit provides coverage to the entire martian surface. Including 2 spacecraft in near polar inclination will maintain global coverage in the event of the loss of any single spacecraft in the constellation.

3. Maximize Coverage/Performance Across all Latitudes and Longitudes.

4. Minimize Coverage/Performance Variations Across all Latitudes and Longitudes. Goals 3 and 4 can be achieved by "tuning" the inclination and altitude of the constellation.

The figure shown below shows an example of data return performance for a candidate constellation that satisfies all of the above design goals. Lowering spacecraft altitude below 600 km produces more variability in data return performance across Mars surface longitudes and latitudes. Data return performance is strongly affected by communications range. Increasing spacecraft altitude above 600 km altitude rapidly reduces communications performance across the entire planet. In summary,

this constellation provides excellent coverage, 200 - 500 Mbit/sol, of the high traffic equatorial region of Mars and consistently good coverage, 150-200 Mbit/sol of the remainder of the martian surface.



A companion paper, entitled "Constellation Design for a Mars-Orbiting Communications and Navigation Network", provides a detailed description of the communications and navigation analysis carried out in the orbital design of the satellite constellation.